Case series demonstrating the clinical utility of dual energy computed tomography in patients requiring stents for urinary calculi

Maria A. Jepperson, MD,[1] David D. Thiel, MD,[2] Joseph G. Cernigliaro, MD,[1] Gregory A. Broderick MD,[2] William E. Haley, MD[3]

[1]Department of Radiology, Mayo Clinic Jacksonville, Jacksonville, Florida, USA

[2]Department of Urology, Mayo Clinic Jacksonville, Jacksonville, Florida, USA

[3]Division of Nephrology, Mayo Clinic Jacksonville, Jacksonville, Florida, USA

JEPPERSON MA, THIEL DD, CERNIGLIARO JG, BRODERICK GA, HALEY WE. Case series demonstrating the clinical utility of dual energy computed tomography in patients requiring stents for urinary calculi. *Can J Urol* 2014;21(1):7166-7170.

Dual energy computed tomography (DECT) utilizes the material change in attenuation when imaged at two different energies to determine the composition of urinary calculi as uric acid or non-uric acid. We discuss a series of case reports illustrating DECT's ability to provide immediate determination of uric acid versus non-uric acid calculi and facilitate more informed clinical decision-making. Further, these cases demonstrate a unique population of patients with ureteral stents and percutaneous nephrostomy tubes that benefit from DECT's ability to create a virtual color contrast between an indwelling device and the stone material and thereby significantly impacting patient morbidity.

Key Words: renal calculi, dual energy computer tomography (DECT), ureteral stents, ureteral calculi, nephrolithiasis

Introduction

Dual energy computed tomography (DECT) is becoming a more widely available method of imaging patients with renal stone disease. DECT utilizes the attenuation difference produced by two different x-ray energies to produce color coded material specific images. Specifically, renal calculi composition can be quantified as uric acid (UA) or non-UA based on changes in x-ray attenuation with near 100% specificity, allowing the diagnosis to be made without invasive intervention and with minimal morbidity to the patient.[1-8]

Accepted for publication October 2013

Acknowledgement
Grant from the National Institutes of Health (Mayo Clinic Urology Research Center grant DK 83007) and the Mayo Clinic.

Address correspondence to Dr. Maria Jepperson, Department of Radiology, Mayo Clinic Jacksonville, 2 East Radiology, 4500 San Pablo Road, Jacksonville, FL 32224 USA

The capability to preoperatively identify UA stones is important, given that UA stones may be managed medically while other stone types often require stone removal or lithotripsy. Prior to the introduction of DECT, medical dissolution therapy could not be offered over surgical intervention at initial presentation since composition of the stone was unknown. With equivalent radiation dose[9] and cost DECT provides all the information contained in conventional CT images as well as stone composition, allowing medical dissolution for the first time to be offered as a primary therapy.[1] Since knowledge of stone composition was never previously available at initial presentation, the question remains as to whether knowledge of stone composition actually changes patient management.

Ureteral stents are also recognized by the DECT scanner and are assigned a color value on material specific images based on their density and chemical composition.[10] The dual energy characteristics of commercially available stents fall into two groups: those similar to UA (red) and those similar to non-UA based stones (blue).[10] This knowledge presents a second potential advantage of DECT; enhanced accuracy of stone identification in the specific setting of patients requiring ureteral stents by virtue of providing a color contrast between the stent and the stone. Further, no other imaging modality is able to create color contrast between a stent and a stone, also raising the question whether better identification of ureteral calculi adjacent to indwelling stents has a clinical impact. We describe a series of case reports illustrating how DECT performed on a SOMATOM Definition Flash (Siemens, Forchheim, Germany) can change clinical decision-making.

Case reports

Case 1

A 60-year-old man presented with left-sided pain and an obstructing distal ureteral stone diagnosed on conventional CT imaging. At the time of presentation the patient was febrile and hypotensive, thus a percutaneous nephrostomy tube was placed to decompress the patient's obstructed collecting system. He was subsequently scheduled for ureteroscopy with stone manipulation and laser lithotripsy of his ureteral calculi approximately 30 days after his discharge from the hospital. Figure 1a shows follow up DECT images acquired immediately prior to the planed surgical intervention; the UA (red) stones in the left kidney clearly contrast with the Cook nephrostomy tube (blue). This information allowed for the cancellation of the planned follow up surgical intervention and substitution with medical treatment. Response to treatment was clearly documented with dissolution of the UA calculus on follow up exam 3 weeks later, Figure 1b.

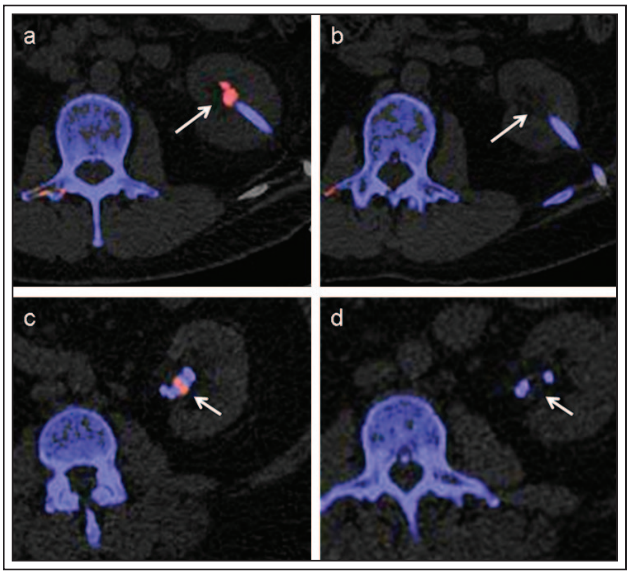

Figure 1. Axial DECT images in two patients **(a, c)** showing uric acid calculi on initial presentation. Post medical treatment images **(b, d)** show a reduced stone burden, confirming a response to dissolution therapy. DE analysis of UA stone composition allowed cancelation of planned interventions and both patients to be treated medically.

Knowledge of stone composition based on DECT imaging facilitated improved medical decision-making. Without the information provided by the dual energy (DE) analysis the patient would have undergone an invasive surgical intervention and potentially increased morbidity. Also, the patient may have continued to form stones without the proper medical therapy. Thus, DECT imaging changed management decisions in both preoperative evaluation and stone prevention.

Case 2

A 50-year-old white female required a ureteral stent for a large left renal pelvis stone. Calculi were discovered to be UA on DECT leading to the decision to treat with alkalinization, Figures 1c and 1d. A response to treatment was clearly documented with a decrease in the size of the UA calculi on the follow up exam.

This patient is an example of how the introduction of DECT at our institution directly altered patient management and reduced morbidity. The patient had suffered from stone disease for many years and had been treated on multiple occasions with extracorporeal shock wave lithotripsy (ESWL). Adequate stone material had not been previously recovered for stone composition analysis. Information provided by DE analysis changed treatment from an additional ESWL to medical dissolution therapy. This change in management not only saved the patient from further surgical intervention but also resulted in dissolution of the calculi and the prevention of future stone events. Again, knowledge of the stone composition provided by DECT resulted in altered management which saved the patient from further morbidity and invasive procedures.

Case 3

A 70-year-old male had a Boston Scientific stent placed for an obstructing non-UA ureteral calculus. DECT imaging allowed clear identification of the stone at the ureteropelvic junction, Figuress 2a and 2b. DE analysis characterized the stone as non-UA (blue) and the Boston Scientific stent similar to UA (red). The improved visibility of the stone adjacent to the contrasting stent is clearly illustrated in this case. Further, the entire contour of the stone is delineated, making the size of the stone easily appreciable.

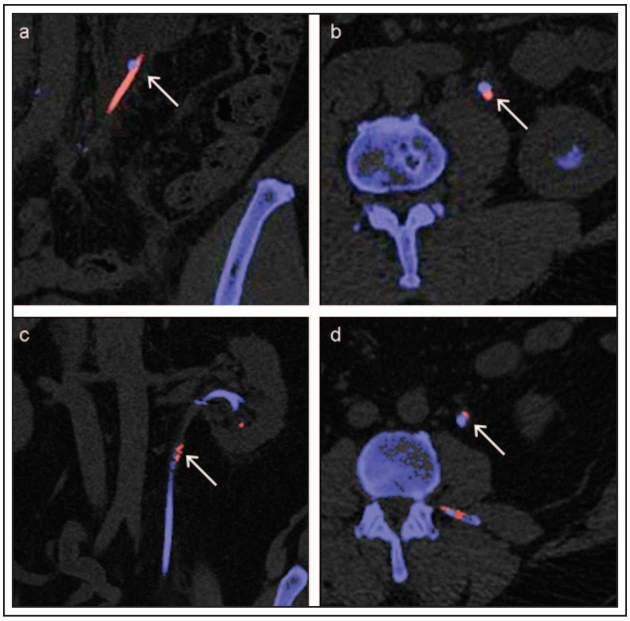

Figure 2. DECT **(a)** coronal and **(b)** axial imaging clearly show the blue non-uric acid calculus (arrow) contrasting with the red Boston Scientific stent. DECT **(c)** coronal and **(d)** axial images clearly show the red uric acid calculi (arrow) contrasting with the blue Cook stent. Clear identification of stone material adjacent to the ureteral stent guided appropriate interventional treatment in both cases.

DE analysis immediately confirms the stone is non-UA and the patient is therefore not a candidate for medical dissolution therapy (unlike in Case 1 and 2). Without the contrast between the stent and the stone provided by DECT images, only the lateral contour of the stone is delineated which grossly underestimates the size of the stone. Easy identification of the retained stone resulted in clinical decision to delay stent removal and perform ESWL. Knowledge of the stone composition allowed for appropriate clinical decision making and minimized patient morbidity.

Case 4

Another case of optimized visualization based on stent/stone color contrasting is that of a 64-year-old man who presented with flank pain and a 3.9 cm left-sided staghorn calculus. He was treated with a percutaneous nephrostolithotomy (PCNL). Follow up DECT identified residual stones that were characterized as UA. Unlike conventional CT views, the color contrast allows for easy discovery of hidden stones in the ureter and in the loop of nephrosotomy tube in the kidney, Figures 2c and 2d.

With the information provided by DE analysis surgical planning was improved. Upon initial inspection of the ureter with a rigid ureteroscope no residual calculi were identified. Since the calculi were well delineated on the DECT images, the urologist decided to use a flexible ureteroscope and was therefore able to find and remove the calculi. Again, easy identification of stone fragments along the course of the nephrostomy tube allowed for improved management decisions. Further, identification of stone composition as UA ensures proper post procedure management and stone prevention strategies.

Case 5

A 64-year-old male was evaluated following ureteroscopic lithotripsy for an obstructing stone. Figure 3 shows DECT performed prior to Bard stent (blue) removal which falsely appeared to show the patient to be stone-free. Upon retrospective review, there was a non-UA stone (blue) fragment adjacent to the stent. Conventional CT images also retrospectively show the camouflaged stone. The patient had multiple

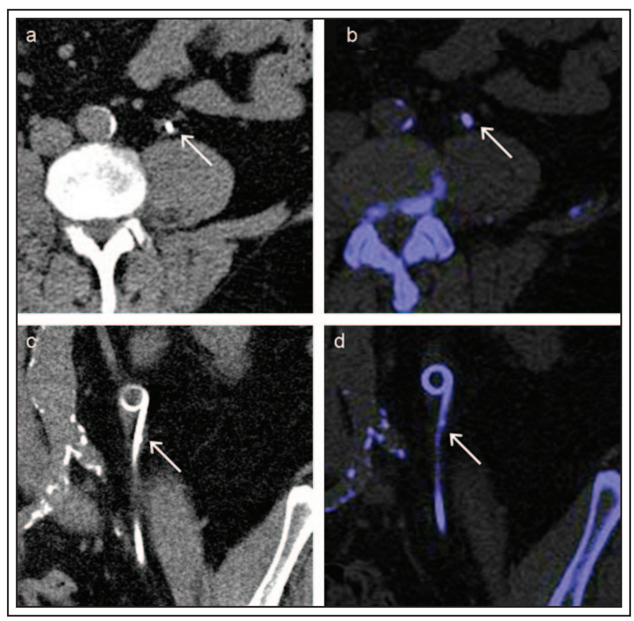

Figure 3. A 64-year-old male with non-uric acid urolithasis and Bard ureteral stent in the left ureter. The retained stone fragment (arrow) is almost imperceptible on conventional CT **(a)** axial and **(b)** coronal images. Both the Bard ureteral stent and the non-UA stone are characterized as blue on DECT **(c)** axial and **(d)** coronal images; also causing nearly complete camouflage of the stone fragment. Identification and quantification of stone size are difficult on conventional CT and DECT images without color contrast between the stent and the stone.

other comorbidities which made him a poor candidate for surgical based interventions. He subsequently was thought to have a stricture, in the region of the retained stone, which was treated with balloon dilation. He was then reevaluated and a stone embedded within the ureteral wall was identified and removed.

Stent/stone contrast on DECT images would likely have allowed for the identification and removal of stone fragments prior to an attempt of balloon dilation. This allows for improved clinical decision making and could have prevented premature stent removal in a complicated patient. This case shows the potential to miss residual stone fragments on both conventional CT imaging and DECT secondary to stent/stone camouflage. As demonstrated by earlier cases, DECT has the ability to overcome this limitation through color contrasting provided by appropriate prospective stent selection prior to placement.

Discussion

As illustrated by the above cases, information provided by DECT can have clinical impact on patient management. This imaging modality is able to provide the information contained in a conventional CT as well as determine stone composition as UA or non-UA, and thereby guide appropriate treatment.[1-8] Alternative imaging modalities such as conventional CT utilizing Hounsefeld Unit measurement and standard abdominal x-ray are unlikely to be able to determine stone composition with the same accuracy as DECT.[1-8] Two of the above cases demonstrate patients whose stone disease was treated surgically prior to DECT imaging and was then changed to medical therapy after DECT imaging. Hence, therapy based on early identification of stone composition provided by DECT can prevent unnecessary surgical intervention and avoid future stone events.

Other than DECT, no other imaging modality is able to create distinct contrast between a ureteral stent and a urinary stone. Ureteral stents are also characterized on DECT images and assigned a color value of UA (red) or non-UA (blue).[10] From a clinical standpoint, residual stones and retained stone fragments following surgical intervention are major predictors of postoperative symptoms and recurrent stone events requiring intervention. As such, the ability of DECT to create a clinically useful color contrast between a stent and a stone has the potential to improve the accuracy of detection and size of residual stone fragments. Hence, DECT with prospective stent selection (red stent with blue stones and vice versa) has the potential to decrease patient morbidity and healthcare costs both through identification of stone composition and identification of residual stone fragments.

Prospective stent selection is only possible if the patient's stone composition is known prior to stent placement. In cases of unknown stone composition, an alternative to performing a second study with DECT protocol would be placement of a stent with the most likely probability of contrast. Since 80%-90% of calculi are non-UA, placing a stent with dual energy characteristics of UA (red) would be recommended. A short reference library of ureteral stent characterization has previously been reported in the literature and can be referenced for stent selection.[10]

An alternative to prospective stent selection would be to develop a universal stent that has a novel DE characterization different than both UA and non-UA stones. This would eliminate the need for knowledge of stone composition prior to stent placement. With current post-processing software this is not an option, since there are only two color categories (red and blue). We anticipate this technology may become available in the future, with continued improvements to image post-processing.

Conclusion

DECT is the only imaging modality able to distinguish renal stone composition, and thereby guide appropriate disease treatment. Further, DECT can create a clinically useful color contrast between stents and stones to improve the detection of residual stone fragments and retained calculi, thereby, also improving patient management decisions. The images and case descriptions included herein demonstrate cases where DECT changed patient management and therefore can have clinical advantage over conventional imaging. Well-designed clinical trials are still needed to determine the specific patient population and clinical settings most benefited by this technology. We expand upon previously reported benefits of use of DECT technology specifically in patients requiring stents for management of urinary calculi. □

References

1. Boll DT, Patil NA, Paulson EK et al. Renal stone assessment with dual-energy multidetector CT and advanced postprocessing techniques: Improved characterization of renal stone composition-pilot study. *Radiology* 2009;250(3):813-820.
2. Graser A, Johnson TRC, Bader M et al. Dual energy CT characterization of urinary calculi: initial in vitro and clinical experience. *Invest Radiol* 2008;43(2):112-119.

3. Matlaga BR, Kawamoto S, Fishman E. Dual source computer tomography: a novel technique to determine stone composition. *J Urol* 2008;72(5):1164-1168.
4. Primak AN, Fletcher JG, Vriska TJ et al. Noninvasive differentiation of uric acid versus non-uric acid kidney stones using dual energy CT. *Acad Radiol* 2007;14(12):1441-1447.
5. Stolzmann P, Kozomara M, Chuck N et al. In vivo identification of uric acid stones with dual-energy CT: diagnostic performance evaluation in patients. *Abdom Imaging* 2010;35(5):629-35.
6. Stolzmann P, Scheffel H, Rentsch K et al. Dual-energy computed tomography for the differentiation of uric acid stones: ex vivo performance evaluation. *Urol Res* 2008;36(3-4):133-138.
7. Thomas C, Patschan O, Ketelsen D et al. Dual-energy CT for the characterization of urinary calculi: In vitro and in vivo evaluation of a low-dose scanning protocol. *Eur Radiol* 2009;19(6):1553-1559.
8. Ferrandino MN, Pierre SA, Simmons WN et al. Dual-energy computed tomography with advanced postimage acquisition data processing: Improved determinate of urinary stone composition. *J Endourol* 2010;24(3):347-354.
9. Yu L, Primak A, Liu X et al. Image quality optimization and evaluation of linearly mixed images in dual-source, dual-energy CT. *Med Phys* 2009;36(3):1019-1024.
10. Jepperson MA, Thiel DD, Cernigliaro JG et al. Determination of ureter stent appearance on dual-energy computed tomography scan. *Urology* 2012;80(5):986-989.